Light-quark two-loop corrections to heavy-quark pair production in the gluon fusion channel

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Abstract: We calculate the two-loop corrections to heavy-quark pair production in the gluon fusion channel which arise from diagrams involving a closed light-quark loop. The calculation is carried out by keeping the exact dependence on the heavy-quark mass. The analytic results are written in terms of logarithms, classical polylogarithms Li_n (n=2,3,4), and genuine multiple polylogarithms $\mathrm{Li}_{2,2}$.$The functional arguments are rationale$
$space points. Through systematic changes in the functional basis, we obtain expansions of the results in both the production thr$

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Benefits of Apprenticeship Training and Recent Challenges – Empirical Results and Lessons from Switzerland and Germany[1]

Uschi Backes-Gellner, University of Zurich

Apprenticeship Training and Academic Education – The Problems of Turning Tides

Apprenticeship training has gained increased attention worldwide due to record highs of youth unemployment. In the US, Barack Obama proposed an $8 billion 'Community College to Career Fund' to promote vocational education. The UK government sponsored a new review of apprenticeships. In South Korea, a new network of vocational schools has been established. Many other countries are paying more attention to apprenticeship training or, more generally, to VET (Vocational Education and Training).

After several decades of focusing on academic education and the ratio of college and university graduates as the sole indicator of the success of a national educational system (pushed by the OECD Education at a Glance publications), it appears that the tides have turned, with widespread praise for apprenticeship training now being fashionable. Following years of a narrow focus on academic education, policymakers worldwide are now more willing to consider alternative means of skill enhancement.

However, over 20 years of praising academic education have left their mark on the individuals involved in educational decisions on academic vs. vocational education, i.e., the young and their parents. The focus on increasing college graduates in public policy debates has led to a perception among parents and children that an academic education is in general the better alternative. Even in countries, where apprenticeship training (in the form of a dual vocational education)[2] offers very good labor market prospects, youngsters (and their parents) are increasingly pushing into universities. This new trend was particularly strong in Germany and noticeable in Switzerland, though to a lesser extent.

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[2] In apprenticeship training in the Swiss or German context, apprentices receive a dual education (in vocational schools and in firms) that usually lasts for three to four years. This process is regulated by federal laws and closely follows training curricula, which are regularly updated in tripartite processes. The set of institutional characteristics is different in Switzerland and Germany. However, in both countries the set of institutions is key to the success of the German or the Swiss apprenticeship system, and parts of the respective institutional settings cannot be abolished without compromising the effectiveness of the whole apprenticeship system.

As a consequence, companies nowadays face increasing difficulty in finding qualified youngsters for their apprenticeship training slots. This difficulty in turn reduces companies' willingness to provide apprenticeship training slots. It thereby triggers a negative downward spiral for the national apprenticeship training system, particularly with shrinking youth cohorts and the increasing pull of youngsters into an academic track. Because these trends are self-enforcing, supply and demand problems are likely to increase despite the variety of benefits of apprenticeship training to individuals and firms that many empirical studies provide evidence for. The negative spiral endangers the quality of the entire dual vocational education and should be a lesson to those countries that are considering establishing new vocational education and training systems.

So obviously, it is not enough to praise the advantages of dual vocational education in public policy speeches. There is also a need to convince young school graduate and their parents and, above all, potential training companies of the benefits of a vocational education. Only if these groups are convinced to gain benefits will there be a sufficient supply of high-quality trainee candidates and of high-quality company training slots in the long run. More and better facts on the costs and benefits of apprenticeship training are thus key to solving the problem. As shown below, recent empirical research suggests that benefits are manifold: but they are often not known well enough among educational decision takers.

Individual Returns to Apprenticeship Training – the Case of Switzerland and Germany

Switzerland is a particularly interesting country in international discussions on apprenticeship training[3] because - unlike Germany - it has a relatively deregulated labor market and thus provides helpful lessons for countries with deregulated labor markets (like the US or UK) who are interested in establishing an apprenticeship training system.

In Switzerland, youth unemployment is, at 7.7%, at a record low in an international comparison, with UK having 20% and USA having 17.3%.[4] Meanwhile, Switzerland scores highest in international innovation indicators and in the percentage of students attending a

[3] Apprenticeship training (or dual vocational education) in Switzerland or Germany relies on a rich set of institutional regulations governing their apprenticeship training systems. Details may be found at http://www.sbfi.admin.ch/aktuell/medien/00483/01323/index.html?lang=en for Switzerland or at http://www.bibb.de/dokumente/pdf/DE_Country_Report_2012.pdf for Germany. More empirical results on the economics of apprenticeship training may be found in the Working Paper series of the Swiss Leading House on Economics of Education, Firm Behavior and Training Policies at http://ideas.repec.org/s/iso/educat.html, or on its website: http://www.educationeconomics.uzh.ch/index_en.html

[4] Labor market statistics: Labor force statistics by sex and age: indicators, OECD Employment and Labor Market Statistics (database), 2011.

world-leading university,[5] but it scores rather low in its share of college graduates in a given cohort. However, a large share of apprenticeship graduates in any given cohort, are part of the Swiss success story. About two thirds of a school leaving cohort decides to go for an apprenticeship training in the dual vocational system at the age of about 16. They are "hired" by a company for an apprenticeship contract and attend for approximately 20% of their workweek a vocational school. Both parts of this dual vocational education follow a well-developed and frequently updated curriculum. As shown below such vocational education generates substantial benefits for the individuals participating in it; apprenticeship graduates are not in a general disadvantage in comparison to graduates from fulltime upper-secondary schools, nor in comparison to graduates from tertiary academic institutions.

Individual Earnings, Job mobility and Unemployment Risk

Empirical research shows that apprenticeship training in Switzerland provides comparatively high incomes with high certainty (e.g. Tuor/Backes-Gellner 2010, Balestra/Backes-Gellner 2013). Tuor/Backes-Gellner (2010) for example show that the internal rate of return for individuals with tertiary education is around 12% if they had chosen a pure vocational path and only 10% if they chose a pure academic path. At the same time the earnings risk (measured by the variation coefficient) is 14% for individuals who chose pure academic path and only 13% for those with a pure vocational path. So for vocational education the risk is lower and the internal rate of return higher is higher than for academic education. Results of Balestra/Backes-Gellner (2013) indicate that although there are significantly higher wage premia for academic education than for vocational education in the upper part of the wage distribution, there are significantly lower wage premia for academic education than for vocational education in the lower part of the distribution.

Having finished an apprenticeship training also offers the possibility to changing jobs in later career steps. Even changes in occupation – especially between occupations, which demand similar skills and competences – are quite frequently observed as Geel/Mure/Backes-Gellner (2011) show and explain based on Lazear's skill weights approach. Changes within occupational groups are even associated with an increase in wages: the income of those who switch occupations increases on average by 6.8%, as Backes-Gellner/Geel (2011) show. Therefore, having completed dual apprenticeship training does not mean that individuals are

[5] For more information on institutional details and data, see "Swiss Education Report" (2010) or its recent German language version "Bildungsbericht Schweiz" (2014).

restricted to one single occupation for the rest of their lives. They have many opportunities to change occupations and their career paths - as long as apprenticeship training provides a bundle of skills and competences[6] that are similar to those demanded by other occupational fields (as is the case in most dual apprenticeship programs). Therefore, apprenticeship training in the form of dual vocational education not only provides smooth entry into the labor market but also opens a wide range of later career opportunities.

Empirical studies for Switzerland also show that individuals who begin their labor market careers with a dual vocational education are at a lower risk of unemployment compared with individuals who began on a pure schooling/academic track. From 1999 to 2005, the unemployment risk of vocational education graduates was 0.7 percentage points lower than that of similar individuals with a pure schooling/academic education. Although more education in general protects better from involuntary dismissal than less education, academic education is not more effective than vocational education in offering this protection once at a tertiary level (Backes-Gellner & Balestra 2012).

In Switzerland, talented dual apprenticeship graduates have many opportunities to climb the education ladder, either by moving on to higher vocational education (tertiary B) or to higher academic education (tertiary A). Empirical results show that transitions between the vocational and the academic system are possible (due to the permeability of the Swiss education system) and that mixed education paths are quite common. Between 1999 and 2005, over 10% of male employees with a tertiary degree followed a mixed educational path (Tuor & Backes-Gellner 2010). These employees either began with a dual apprenticeship and later pursued an academic education or began on an academic track (obtained a Matura) and later pursued higher vocational education.

Regarding labor market outcomes, a pure academic path does not necessarily lead to the highest income. A mixed educational path is for many even more rewarding in Switzerland. An individual with a mixed educational path, i.e. with a vocational education degree and a college degree (often via universities of applied sciences) receives a 32% higher income than a university graduate who has followed a pure academic path. One of the reasons for this difference is that work experience and theoretical knowledge complement each other in mixed educational paths (Tuor & Backes-Gellner 2010). In addition, Backes-Gellner/Tuor/Wettstein (2010) find that, individuals with a mixed educational path, i.e. with a combination of

[6] Based on Lazear's skill weights approach, the individual combination of skills in comparison to the skill combination on the external labor market determines workers' long-term labor market prospects (Lazear 2009).

academic and vocational education, are also very likely to become entrepreneurs - as can be expected according to Lazear's (2005) Jack-of-all-Trades theory.

Therefore, individuals who change their career paths and move from vocational to academic education or the other way around at later career stages obviously complement their existing skills, i.e., complement professional skills with academic knowledge or vice versa, and are rewarded in the labor market for doing so.

Company Benefits of Participating in Apprenticeship Training

Generally firms also only willing to train as long as they expect sufficient benefits to cover their training costs, either in the short run or the long run. These benefits can occur during the training period if apprentices' productivity is higher than their training costs. Dionisus et al (2009) show that this is the case for most Swiss training companies, but not for German companies. Or these benefits can occur after the training period due to better retention of high quality apprenticeship graduates or due better recruitment options on the external labor market (if apprenticeship training serves as a signal for high quality employment relations as shown by Backes-Gellner/Tuor 2010). As Dionisus et al (2009) show, Swiss firms rely more on short term benefits during the training period whereas German firms, who are not able to gain sufficient benefits during the training period, rely more on long term, post-training benefits.[7] Accordingly, Mühlemann et al (2010) show, that Swiss 'non-training firms' abstain from training apprentices because their net costs in the training period would be too high, and German 'non-training firms' abstain from training apprentices because they expect lower post-training benefits. Thus, for Switzerland, with its flexible labor market regulations and highly mobile labor force, it is crucial that training firms are able to break even during the apprenticeship training period. For Germany, with its tightly regulated labor markets, it is crucial that German firms are able to generate and rely on long-term post-training benefits within their internal labor market.

[7] Dionisus et al (2009) show that German firms are faced with substantial net-costs during the training period, and that Swiss firms are able to generate net-benefits during the training period. Most of the difference in the net-costs between the two countries results from a higher share of productive tasks allocated to apprentices in Switzerland and from the relative wages of trainees and skilled workers.

The Role of Apprenticeship Training for Innovation

Although the innovation literature typically assumes that university graduates (academically qualified workers) are the most important human capital input to foster innovation, for the cases of Switzerland and Germany, it can be shown that apprenticeship graduates and workers with high-quality vocational education are as essential for their innovation (Rupietta & Backes-Gellner 2012). In both countries, innovation in companies is fostered by the collaboration of highly skilled university graduates with highly skilled apprenticeship graduates, i.e. by the combination of abstract academic skills with sound occupational knowledge.[8] To the contrary, innovation appears to be hampered in companies in which academically qualified workers only have unskilled workers to collaborate with, because they lack the knowledge and professional language link that vocational workers provide (Teuber & Backes-Gellner 2012). To bridge the gap e.g. between engineers and production workers and to spur innovation, well-educated vocational workers are needed as a complement to the engineers.

Apprenticeship Training as a Source of Competitive Advantage

With its high-quality dual vocational education system, Switzerland or Germany possess an education system that is able to provide a large share of its young generation with competitive and sustainable qualifications. Both countries are also able make a large share of their companies participate in dual vocational education, which not only helps to share the burdens of training but also guarantees a good fit between the qualifications and skills of the young generation and the (changing) labor market demands, structural shifts and technological changes.

A dual vocational education system proves to be an important national competitive advantage, which is based on several (historically evolved) pillars. On the one hand, it is based on two complex, although different systems of tripartite institutions, which ensures a high-quality vocational education for a large share of a country's labor force, a high participation of small and large companies in the country's training burden, and a systematic improvement of vocational curricula in accordance with companies' actual and future needs. On the other hand, it enables a high mobility of individual workers in internal and external

[8] For more information on the German case see also the 2014 annual report of the Commission of Experts for Research and Innovation (2014).

labor markets and guarantees sound returns such as increased income and reduced unemployment, thereby ensuring the attractiveness of a dual vocational education among talented young students (despite a very modest apprentice pay).

Meanwhile, the availability of talented young students for an apprenticeship training with a modest apprentice pay, ensures the acceptance and strong commitment of companies to participate in dual vocational education and take their share of the burden.[9] Therefore, dual vocational education institutions that guarantee high-quality, up-to-date training standards on the one hand and a high acceptance of apprenticeship training among youths and their parents on the other hand, are key to the success of a country's apprenticeship training system. The challenge will be to sustain these conditions in a world with an increasing number of multinational companies that are not familiar with the system, with an increased international workforce coming from countries with different educational backgrounds,[10] and with the foreseeable demographic changes of declining youth cohorts.[11]

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[9] The particular role and determinants of wages for apprenticeships across different national institutional settings are discussed in Ryan/Backes-Gellner/Teuber/Wagner (2013).

[10] Cattaneo/Wolter (2013), for example, show that foreign citizens have a significantly stronger preference for an academic education over a vocational education compared to natives. This difference may be partly due to insufficient information but nevertheless spurs the tendency towards more academic education.

[11] Mühlemann/Pfeifer/Wenzelmann (2013) show in this context that shortages in the (local) supply of apprentices increase recruitment costs of apprenticeship candidates, which can be expected to reduce the net-benefits and the willingness to train if nothing else is adjusted. Mühlemann/Brändli/Wolter (2013) also show that a firm's training strategy depends on trainee's ability. Firms usually prefer higher-ability trainees but are also willing to accept lower-ability trainees and compensate them with additional training if - given the training regulations they face - allows them to gain net-benefits. Therefore, when training regulations induce net-costs under normal circumstances, low-ability trainees will not receive additional instruction time, and the dropout risk increases. Only with national regulations that enable firms to generate net-benefit from apprenticeship training can firms be expected to help addressing the problem of low-ability trainees by making additional training investments. Mohrenweiser (2013) shows for the case of Germany that firms with greater training capacity (with more full-time instructors and their own designated training facilities) are also more willing to participate in the training of disadvantaged youths. Thus, depending on the regulatory and firm-internal circumstances, companies not only play an important role in training the highest occupational skills to high-ability youngsters, but they also play an important role in integrating the most disadvantaged youth.

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